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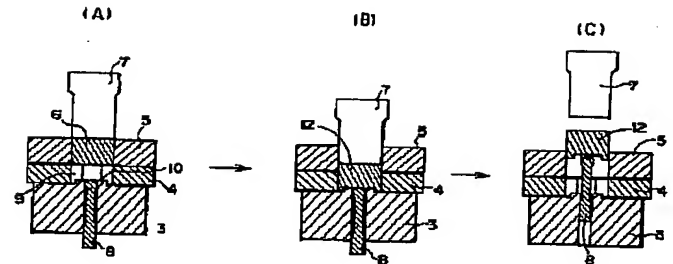
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INT.CL. : B21K 1/00 B21J 1/06 B21J 19/04

TITLE : PRODUCTION OF ALUMINUM ALLOY
ROTOR STOCK AND ALUMINUM
ALLOY ROTOR STOCK



ABSTRACT : PROBLEM TO BE SOLVED: To reduce a cutting margin, to improve a yield and to reduce a cutting time by forming so that a forged stock is penetrated into the outer peripheral side of a projecting part formed to a diameter smaller than a rotor stock outer diameter and cutting/removing the part protruding longer than the center part at the outer peripheral part of a forged part.

SOLUTION: An area of a projecting part as an anvil in a range of 30 to 90% of the area of the end face of a rotor stock is preferably used. Further, a height of the projection part as the anvil in a range of 0.3 to 10 mm is used. The projecting part 10 is protruded to a disk shape smaller than a die inner diameter to be the anvil 4, a die vane part 9 is arranged to a die 4. By charging a blank 6 and descending a press punch 7, a vane accommodation groove is formed, a stock is penetrated into a cavity of the outside part of the projecting part 10. A forged part 12 is taken out by a knock out pin 8, the outer peripheral projecting part having width spreading to the vane accommodation groove and a remaining excess length part of extrusion are removed by machining.

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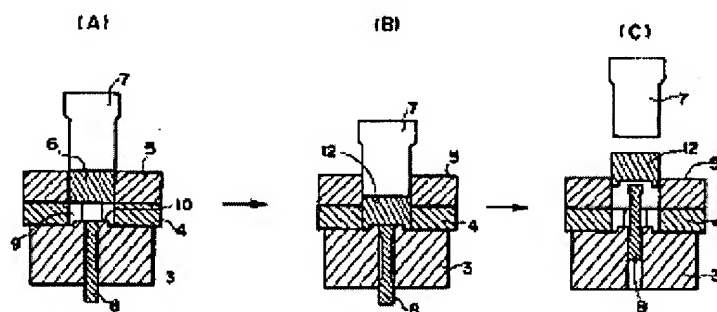
(54) [Title of the Invention] **Manufacturing Method of Aluminum Alloy Rotor Billet,
and Aluminum Alloy Rotor Billet**

(57) [Summary]

[Object] To minimize the cutting allowance, to enhance yield, and to reduce the cutting time in the manufacture of an aluminum alloy rotor billet by hot press forging when a forging that is longer than the actual required dimensions is obtained and the vicinity of the end face with widened vane-containing grooves is cut off in order to enhance the dimensional precision of the vane-containing grooves.

[Means of Achievement] A projection whose diameter is smaller than the outside diameter of the rotor billet is formed on the upper surface of an anvil positioned under die blade portions for

forming vane-containing grooves, and forging is performed so that material enters the outer peripheral region of the projection during forging of the rotor billet, whereby a forging is obtained that is formed such that the outer periphery thereof protrudes farther than the central portion thereof, and the portion in the outer periphery that protrudes farther than the central portion is then removed by cutting.



[Claims]

[Claim 1] A manufacturing method for an aluminum alloy rotor billet whereby an aluminum alloy rotor billet having a plurality of vane-containing grooves shaped by cutting from the external peripheral surface thereof is manufactured by hot press forging, characterized in that a projection whose diameter is smaller than the outside diameter of the rotor billet to be obtained is formed on the upper surface of an anvil positioned under the die blade portions for forming the vane-containing grooves and forging is performed so that forging material enters the outer peripheral region of the projection during forging, whereby a forging is obtained that is formed such that the outer periphery thereof protrudes farther than the central portion thereof, and the portion in the outer periphery that protrudes farther than the central portion is then removed by cutting.

[Claim 2] The manufacturing method for an aluminum alloy rotor billet according to claim 1, wherein an anvil is used having a projection whose surface area is in a range between 30% and 90% of the surface area of the end face of the rotor billet.

[Claim 3] The manufacturing method for an aluminum alloy rotor billet according to claim 1, wherein an anvil is used having a projection whose height is in a range between 0.3 mm and 10 mm.

[Claim 4] An aluminum alloy rotor billet obtained by the manufacturing method according to any of claims 1 through 3.

[Detailed Description of the Invention]

[0001]

[Technological Field of the Invention] The present invention relates to a method of manufacturing an aluminum alloy rotor billet used in a rotor for a rotary compressor, a rotary vacuum pump used for brake control, or another unit mounted in an automobile.

[0002]

[Prior Art] Aluminum alloy rotors are becoming widely used in rotary compressors, rotary vacuum pumps used for brake control, and other units mounted in automobiles, mainly for weight reduction. On the other hand, the rotor billet 1 used in the fabrication of such rotors is generally in a short cylindrical shape overall, as depicted in FIGS. 12 and 13, for example, and has a shape in which a plurality of grooves (vane-containing grooves) 2 for holding the vanes are formed from the external peripheral surface towards the inside. The vane-containing grooves 2 are also formed such that the centerline 2a in the cut direction thereof is in a position that is deflected (offset) by a prescribed distance d from the outside diameter line 1a of the rotor billet 1. The vane-containing grooves 2 are therefore cut from the external peripheral surface of the short cylindrical rotor billet in a direction that is tilted a prescribed angle with respect to a line through the cutting position that is in the radial direction of the rotor billet. In order to actually make a rotor from this type of rotor billet 1, a hole is usually formed by machining in the center of the rotor billet 1 for inserting a shaft, and then other machining or heat treatment is performed to obtain the desired dimensions.

[0003] Hot press extrusion has been the conventional mainstream for methods of manufacturing rotor billets such as described above. This method specifically is a process whereby a rod is extruded while hot by using an extrusion die having blade portions that protrude towards the inside of the die so as to correspond to vane-containing grooves, an elongated extruded product having vane-containing grooves is obtained, and the elongated extruded product is cut in a round slice to obtain a rotor billet. Employing this type of hot press extrusion method has the advantage of being able to manufacture a rotor billet with high efficiency because multiple rotor billets can

be obtained from a single extruded product; however, this method has drawbacks whereby severe torsion and bending occur, particularly when using an elongated extruded product, which inevitably affects the dimensional and positional precision of the vane-containing grooves in the rotor billets obtained by cutting the extruded product into round slices.

[0004] Specifically, because the blade portions of the extrusion die for forming the vane-containing grooves protrude in tilted fashion with respect to the radial direction from the internal peripheral surface of the die, the plastic flow (flow) of the material during extrusion becomes unbalanced on both sides of the die blade portions, whereby uneven residual stress occurs in the extruded product, and torsion and bending are more likely to occur in the extruded product due to the residual stress, and the effects thereof are particularly severe in the case of an elongated extruded product. Only a rotor billet with low dimensional and positional precision of the vane-containing grooves is obtained if an extruded product with such severe torsion and bending as described above is cut into round slices to produce a rotor billet. This type of hot press extrusion also has drawbacks in that the surface properties of the product are easily affected and cracks tend to form in the surface due to the difficulty of lubricating between the die and the material.

[0005] On the other hand, a method of manufacturing a rotor billet by hot press forging that uses stamp forging has recently been developed. As depicted in stepwise fashion in (A) through (C) of FIG. 14, this method involves a process in which a forging die 4 and case 5 are positioned on top of an anvil (surface plate) 3, a forging material (blank) 6 heated in advance to the hot press forging temperature is inserted into the case 5 from above, the blank 6 is pressed by a pressing punch 7 and forge molded in the die 4 to form a forging 12, and the forging 12 is then pushed out by a knockout pin 8. The die 4 in this arrangement is shaped so that a plurality of blade portions 9 corresponding to vane-containing grooves protrude from the internal peripheral surface thereof, and vane-containing grooves 2 are formed in the forging by the blade portions 9.

[0006] The same unbalance in plastic flow on both ends of the die blade portions during forging as in hot press extrusion also cannot be avoided when manufacturing a rotor billet by hot press forging as described above, but because a rotor billet of one short length is forged in a single forging, the effects of residual stress due to unbalanced plastic flow are lessened in comparison to extruding an elongated rod, thus enabling a rotor billet with high dimensional precision to be obtained, and a rotor billet with good surface properties and less risk of cracking can also be obtained because of the ease of lubrication.

[0007]

[Problems to Be Solved by the Invention] The drawbacks of hot press extrusion can be overcome to a certain extent when manufacturing a rotor billet by hot press forging as previously described; however, new drawbacks also occur.

[0008] Specifically, hot press forging has drawbacks in that it is difficult during forging to adequately fill the material into the corner formed at a right angle between the upper surface of the anvil and the lower edge of the die, particularly, at the corners on both sides of the base ends of the die blade portions, so-called "sagging" thus occurs on the edges of the vane-containing grooves that correspond to the above-mentioned corners, the width of the vane-containing grooves enlarges particularly at the periphery of the end face of the product, and the dimensional precision of the vane-containing grooves declines.

[0009] It is considered to be possible, at least in theory, to adequately fill the material into such corners as described above and to prevent the drawback of enlarged width of the vane-containing grooves by adequately increasing the forging load, but this leads to drawbacks whereby the load applied to the die becomes excessive and the service life of the die is shortened, and the die blade portions are deformed by the large load applied to the die, whereby the dimensional precision of the vane-containing grooves declines. On the other hand, the aforementioned drawbacks can be overcome to a certain extent if the plastic flow speed of the material during forging is slowed through a reduction in the forging speed, but this case has the drawback of reduced productivity.

[0010] Furthermore, a back pressure forging method may be employed whereby the material is depressed while applying a load in the direction opposite the forging direction to the leading edge surface of the material during forging, and it becomes possible by means of this back pressure forging method to high-precision mold the leading edge of the material, to which the load is not easily transferred, and it may also be possible by adapting this method to rotor billet forging to adequately fill the material into cracks such as described previously, and to obtain a rotor billet with high dimensional precision. However, employing the back pressure forging method presents equipment constraints in that an expensive specialized forging press is required.

[0011] A method whereby a forging is fashioned to longer dimensions than actually necessary (specifically, dimensions in which a machining allowance is added to the product dimensions), and the vicinity of the end face of the forging with an increased groove width is cut off is now employed as a practical measure for overcoming these drawbacks, but this method leads to

significant increases in the material charge and the cutting allowance, the yield decreases sharply, and the necessary cutting time increases, which results in inevitable increases in the cost of rotor billets.

[0012] The present invention was developed in view of the foregoing drawbacks, and an object thereof is to obtain a rotor billet with high dimensional precision by cutting off the portion in the vicinity of the end face of a forging in which widening of the vane-containing grooves occurs directly after forging in the manufacture of a rotor billet by hot press forging, whereby the cutting allowance of the forging can be minimized, the yield enhanced, and the finishing and cutting time shortened to reduce the cost of manufacturing the rotor billet.

[0013]

[Means Used to Solve the Above-Mentioned Problems] Aimed at addressing the above-described problems, the method for manufacturing a rotor billet in accordance with the present invention is essentially a manufacturing method for an aluminum alloy rotor billet whereby an aluminum alloy rotor billet having a plurality of vane-containing grooves shaped by cutting from the external peripheral surface thereof is manufactured by hot press forging, wherein this method is characterized in that a projection whose diameter is smaller than the outside diameter of the rotor billet to be obtained is formed on the upper surface of an anvil positioned under the die blade portions for forming the vane-containing grooves, and forging is performed so that forging material enters the outer peripheral region of the projection during forging, whereby a forging is obtained that is formed such that the outer periphery thereof protrudes farther than the central portion thereof, and the portion in the outer periphery that protrudes farther than the central portion is then removed by cutting.

[0014] In this arrangement, the surface area of the projection on the aforementioned anvil is preferably in a range between 30% and 90% of the surface area of the end surface of the rotor billet, and the height of the projection is preferably in a range between 0.3 mm and 10 mm.

[0015] The present invention also provides a rotor billet obtained by a manufacturing method such as described above.

[0016]

[Embodiments of the Invention] Embodiments of the present invention will be described in detail with reference to FIGS. 1 through 9.

[0017] FIGS. 1 and 2 are diagrams depicting an example of an anvil in the forging die used in an embodiment of the present invention; specifically, an example of the anvil 3 formed with the projection 10 that is characteristic of the present invention. In the diagrams, the anvil 3 is configured with an upward-protruding projection 10 formed on the upper surface of an anvil base 3A in the same overall flat disk shape as an anvil in a die used in conventional rotor billet forging in general, and has a through-hole 11 in the center of the anvil 3 leading up and down in the thickness direction through which a knockout pin passes the same as conventionally.

[0018] The aforementioned projection 10 is formed so as to protrude upwards in an overall disk shape with a diameter smaller than the inside diameter of the die described hereinafter (which is the outside diameter of the rotor billet to be obtained). As described hereinafter, a plurality of notches 10A are formed from the external periphery of the projection 10, into which the lower leading edges of the die blade portions for forming vane-containing grooves in the rotor billet are inserted. Also, in this example, the upper surface 10B of the projection 10 forms an even level surface, the rim of the upper surface 10B thereof drops off substantially vertically, the external peripheral surface 10C forms a substantially vertical cylindrical surface, and the corner 11 formed by the lower edge of the external peripheral surface 10C and the upper surface of the aforementioned anvil base 3A is also at a substantially right angle.

[0019] The process of forging the rotor billet using a forging die equipped with an anvil 3 having a projection 10 such as depicted in FIGS. 1 and 2 will next be described in stepwise fashion with reference to (A) through (C) of FIG. 3.

[0020] A billet-shaped (columnar) aluminum alloy material is cut to a prescribed length in advance as material for forging, the product is heated to a prescribed forging temperature, and is placed in the case 5 as a blank 6 as depicted in (A) of FIG. 3. The volume of the blank 6 is set in advance to a volume that is greater than the necessary volume of the rotor billet as described hereinafter by a combined volume that comprises the volume of the portion in the external periphery of the forging that protrudes from the center thereof and the volume of the overlong portion left over from pressing. The inside diameter of the case 5 is set the same as the inside diameter of the die 4 or somewhat larger than the inside diameter of the die so that knockout of the billet after forging is performed smoothly.

[0021] After inserting the blank 6 as described above, a pressing punch 7 is lowered from above to press the blank 6 into the die 4 for compression forging. In FIG. 3, (B) depicts the stroke of

the pressing punch 7 at its lowermost end. Vane-containing grooves 2 are formed in the material of the blank 6 by the die blade portions 9 during the process in which the blank 6 is pushed into the die 4. With the center of the bottom surface of the blank 6 then in contact with the projection 10 on the anvil 3, the blank 6 is pushed further downward, and material enters the empty space in the external periphery of the projection 10. The forging 12 formed by compression forging the blank 6 is thus shaped such that the external periphery (the portion corresponding to the external peripheral side of the projection 10) protrudes farther downward than the center thereof (the portion facing the projection 10 on the anvil 3).

[0022] The knockout pin 8 is then raised as depicted in (C) of FIG. 3, and the forging 12 is pushed out and ejected from the die 4 and case 5.

[0023] The shape of the forging 12 obtained in this manner is depicted in FIGS. 4 and 5. As depicted in these figures, the overall length L of the forging 12 is equal to the total of the length La of the overlong portion 12A left over from pressing (which is the portion usually encountered in a conventional forging for a rotor billet), the length Lb of the portion 12B of the rotor billet ultimately obtained, and the length Lc of the external peripheral protruding portion 12C corresponding to the external side of the projection 10 on the anvil 3 during forging. Specifically, the external periphery of the resultant forging protrudes a length Lc farther than the center thereof. Also, the vane-containing grooves 2 extend from the portion 12B (with length Lb) of the ultimately obtained rotor billet all the way to the end surface of the external peripheral protruding portion 12C (with length Lc) thereof. In this arrangement, the width of the vane-containing grooves 2 tends to increase near the end surface of the external peripheral protruding portion 12C with the length Lc, particularly at the periphery thereof, which is the same as in the case of the prior art already described, but the external peripheral protruding portion 12C is removed by the cutting process described hereinafter, and does not remain in the final product, so enlargement of the groove width presents no particular problem.

[0024] The external peripheral protruding portion 12C of length Lc is then removed by cutting or other machining from the forging 12 obtained in the above-mentioned manner, and the overlong portion 12A left over from pressing is also removed by cutting in the same manner. Rotor billets as depicted in FIGS. 13 and 14 are thus obtained.

[0025] Solution treatment/artificial aging treatment, specifically, so-called T6 treatment is usually furthermore performed to manufacture a rotor using a rotor billet such as described

above. The conditions of this T6 processing are not particularly limited and vary according to the component composition of the aluminum alloy used, but generally after solution treatment and hardening at approximately 500 to 540°C, artificial aging treatment is performed at approximately 165 to 205°C for 10 hours or longer. A through-hole for inserting a rotor shaft is then formed in the center thereof by machining, the external periphery is furthermore cut and the inner surface of the vane-containing grooves is ground, and the surface thereof is then fluorinated as needed.

[0026] Widening of the vane-containing grooves near the end surface as described previously occurs often at the forging 12 stage in the process described above, but because that portion is removed by cutting off the external peripheral protruding portion (overlong portion) 12C, the portion exposed in the rotor billet step after cutting consists of the portion at the end of the vane-containing grooves in which there is no widening. Specifically, a rotor billet is obtained with high dimensional precision. Also, only the external periphery of the portion 12C of length L_c removed by cutting in this arrangement protrudes downward, and a concave portion whose bottom surface faces the projection in the anvil is formed therein, so the volume of the portion to be removed by cutting can be markedly smaller than in a conventional case in which a concave portion as described above does not exist. Material input for forging and the amount of cutting are thereby reduced, and the time required for cutting is shortened.

[0027] The effects whereby the material input for forging and amount of cutting are reduced are not adequate when the surface area (surface area as viewed from the die) of the projection on the anvil is excessively small in relation to the end surface of the rotor billet in the above-mentioned arrangement, and the surface area of the projection 10 must also be within an appropriate range, because it is difficult to adequately fill material into the gap surrounding the projection during forging if the surface area of the projection is too large. It was discovered from experimentation by the inventors that the surface area of the projection 10 must be between 30% and 90% of the surface area of the rotor billet end surface, and that within that range, a range between 65% and 85% is particularly preferred.

[0028] Also, if the projection 10 on the anvil 3 is too low, the length of the external peripheral protruding portion 12C removed after forging is shortened, and thus the portion in which the width of the vane-containing grooves 2 is widened cannot be adequately removed; alternatively, if the projection 10 is too high, it becomes difficult to adequately fill material into the gap

surrounding the projection 10, and so the height of the projection 10 must also be within an appropriate range. It was discovered from experimentation by the inventors that a suitable height for the projection 10 is within a range of 0.3 mm to 10 mm, and a range of 0.5 mm to 7 mm is optimal.

[0029] Furthermore, the projection 10 has a round shape (disk shaped) as viewed in two dimensions in the aforementioned examples depicted in FIGS. 1 and 2, but this round shape is not limiting. However, a round shape yields good symmetry in the flow of material during forging, and machining of the projection 10 is also easy, and because cutting off of the projection 10 is made easy by the continuous nature of cutting when the external peripheral protruding portion of the forging formed around the projection 10 is cut off, a round shape for the projection 10 is optimal. Also, the upper surface 10B of the projection 10 forms an even level surface, and the external peripheral surface 10C forms a substantially cylindrical surface in the examples depicted in FIGS. 1 and 2, but a tilted surface 10D descending towards the perimeter may be formed on the upper surface of the projection 10 as depicted in FIG. 6, or a bent portion 10E that curves along the external periphery from the upper surface of the projection 10 may be formed as depicted in FIG. 7, so that the material easily extends around the projection 10 during forging. Furthermore, the upper surface 10B and external peripheral surface 10C of the projection 10 form a substantially vertical joint, and the corner 11 formed by the external peripheral surface 10C of the projection 10 and the upper surface of the anvil base 3A is also at a substantially right angle in the examples depicted in FIGS. 1 and 2, but it is also apparent that the joint and corner may be curved into a bent shape, or may form tilted surfaces.

[0030] Furthermore, a plurality of notches 10A are formed in the projection 10 facing the lower leading edges of the die blade portions, and the lower leading edges of the die blade portions 9 fit into the notches 10A in the examples depicted in FIGS. 1 and 2, but these notches 10A are not designed for fixing the die blade portions 9. Specifically, a method of fixing (backing up) the lower portions of the die blade portions in order to prevent slanting deformation of the die blade portions is proposed in JP (Kokai) No. H3-138043, for example, but it was discovered from experimentation by the inventors that when the lower portions of the die blade portions are completely immobilized, significant torsion occurs with the upper unfixed portion of the die blade portions, and dimensional precision of the vane-containing grooves declines. Consequently, it is preferred that the lower portions of the die blade portions not be fixed to the

projection when employing the method of the present invention, and it is therefore preferred that there be a clearance provided between the projection and the die blade portions so as to allow movement of the die blade portions during forging. In this arrangement, the amount of movement in the die blade portions during forging varies according to the shape and dimensions of the blade portions, their material, forging pressure, and the like, but torsion deformation of the die blade portions can generally be prevented if a clearance of 0.1 mm or more is provided.

Specifically, a clearance of 0.1 mm or more is preferably provided between the lower edge face of the die blade portions 9 and the notches 10A of the projection 10 in the examples depicted in FIGS. 1 and 2. The maximum clearance is also not particularly specified, but is preferably about 0.5 mm or less so that entry of material into the clearance during forging is minimized.

[0031] Also, a configuration need not be adopted wherein notches 10A are formed in the projection 10 into which the lower portion of the die blade portions 9 fits, and in some cases notches 13 facing the projection 10 may be formed in the bottom of the die blade portions 9 as depicted in FIG. 8 without forming notches in the projection 10 such as described previously, or the lower edges of the die blade portions 9 may be suspended from the upper surface of the anvil base 3A as depicted in FIG. 9 without forming such notches 13.

[0032] Furthermore, the projection 10 need not be integrally formed with the anvil base 3A, and a projection-shaped member may be created separate from the anvil base 3A, and the member may be fixed on the anvil base 3A by a bolt or other appropriate securing means.

[0033]

[Working Examples] A rotor billet was made according to the following procedure as a working example of the present invention.

[0034] A die 4 of the shape and dimensions depicted in FIGS. 10 and 11 was used for forging. Specifically, the die 4 had an internal diameter R of 62.5 mm, 5 blade portions 9, an offset distance d of the centerline of the die blade portions 9 of 4.8 mm with respect to the diameter line of the inside diameter of the die, a protrusion length of the blade portions 9 into the inside of the die of 18 mm, a width t of 3.2 mm of the blade portions 9, and a height h of 51 mm of the blade portions 9. Also, an anvil 3 was used having a disk-shaped projection 10 as depicted in FIGS. 1 and 2. The outside diameter of the projection 10 was 44 mm, the height thereof was 5 mm, and the surface area of the projection 10 was approximately 52% of the surface area of the end surface of the rotor billet to be obtained.

[0035] A columnar blank of A390 aluminum alloy with an outside diameter of 61.3 mm was used as material for forging (blank), the blank was preheated to 300 to 460°C, the die and pressing punch were preheated to 100 to 350°C, and hot press forging was performed with a load of 20 to 100 tons. The end surface (on the side of the external peripheral protruding portion) of the resultant forging was cut off to a distance of 5 mm, and a rotor billet was obtained.

[0036] On the other hand, as a comparative example, hot press forging was performed to obtain a forging, the end surface thereof was cut off to a distance of 5 mm, and a rotor billet was obtained in the same manner as described previously except that an anvil without a projection 3A was used.

[0037] The portions of the rotor billets obtained in the working example and comparative example in which widening of the vane-containing grooves occurred were removed by cutting of the forging, and the final product had high dimensional precision. In the working example and comparative example, a reduction of approximately 17 g of material input for forging was achieved in the working example in comparison to the comparative example, and material cost was reduced. Also, approximately 30 seconds in the comparative example and approximately 15 seconds in the working example were required for cutting the forging, which also showed a reduction in time required for the cutting operation in the working example.

[0038]

[Effect of the Invention] By means of the method of the present invention, when manufacturing a rotor billet by hot press forging whereby a forging is fashioned to a longer length than the actual required dimensions thereof and the vicinity of the end surface of the forging with widened vane-containing grooves is cut off to obtain a rotor billet having vane-containing grooves with high dimensional precision, the input quantity of material for forging and the cutting allowance can be reduced, thereby allowing enhanced material yield, and cutting time can be shortened, thereby enabling significant reduction of material cost and manufacturing cost compared to the conventional method, by a process in which a projection with a smaller diameter than the outside diameter of the rotor billet is formed on the upper surface of the anvil, forging is performed so that the forged material reaches to the external periphery of the projection during forging of the rotor billet to obtain a forging whose external periphery protrudes farther than the center thereof, and the external peripheral protruding portion thereof is then cut off to allow the portion with the widened vane-containing grooves to be removed.

[Brief Description of the Drawings]

[Figure 1] A plan view depicting a first example of an anvil with a projection used in the method of the present invention.

[Figure 2] A vertical front view of the anvil depicted in FIG. 1.

[Figure 3] A schematic vertical cross-sectional view depicting an example of the implementation of the method of the present invention in stepwise fashion, wherein (A) is a vertical cross-sectional view depicting a state in which a blank is inserted directly prior to the start of forging; (B) is a vertical cross-sectional view depicting the state just after forging; and (C) a vertical cross-sectional view depicting the state when the forging is ejected.

[Figure 4] A bottom plan view depicting an example of the forging obtained by the method of the present invention in the state before cutting.

[Figure 5] A cross-sectional view from line V-V of the forging depicted in FIG. 4.

[Figure 6] A vertical front view depicting a second example of the anvil used in the method of the present invention.

[Figure 7] A vertical front view depicting a third example of the anvil used in the method of the present invention.

[Figure 8] A longitudinal sectional front view depicting another example of the forging die used in the method of the present invention.

[Figure 9] A vertical front view depicting yet another example of the forging die used in the method of the present invention.

[Figure 10] A plan view of the anvil used in the working example of the present invention.

[Figure 11] A vertical front view from line XI-XI in FIG. 10.

[Figure 12] A plan view depicting an example of the rotor billet to be manufactured by the method of the present invention.

[Figure 13] A vertical front view from line XIII-XIII in FIG. 12.

[Figure 14] A schematic vertical cross-sectional view depicting in stepwise fashion an example of a conventional method for manufacturing a rotor billet by hot press forging.

[Key]

1: rotor billet

2: vane-containing grooves

3: anvil

3A: anvil base

4: die

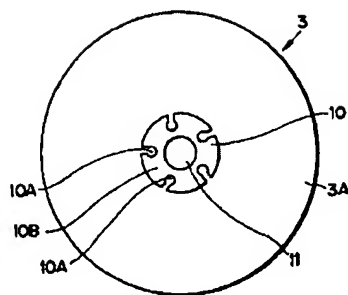
6: blank (material for forging)

9: die blade portions

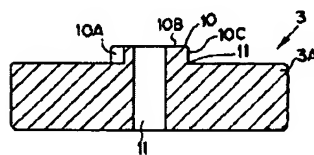
10: projection

12: forging

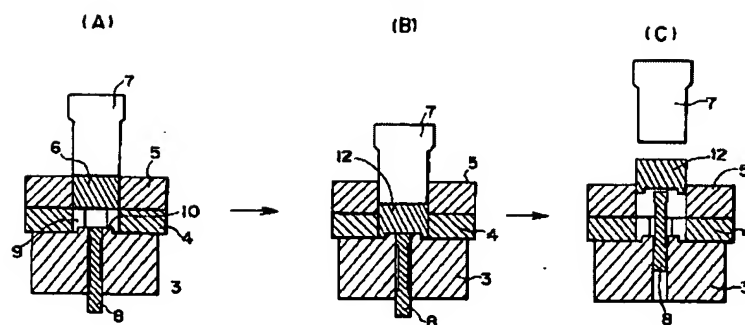
[FIG. 1]



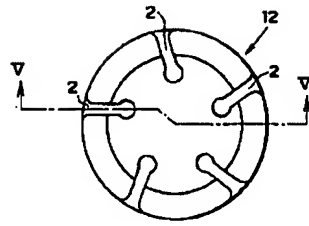
[FIG. 2]



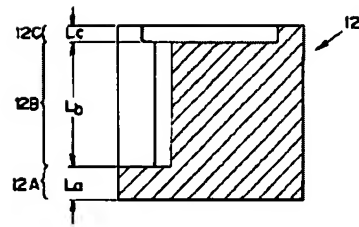
[FIG. 3]



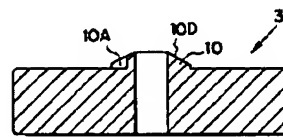
[FIG. 4]



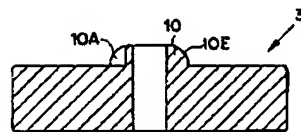
[FIG. 5]



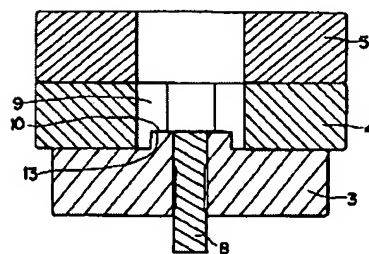
[FIG. 6]



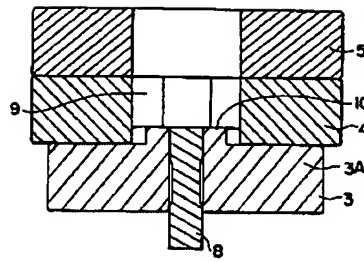
[FIG. 7]



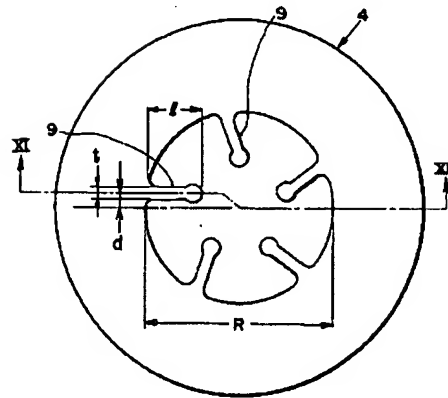
[FIG. 8]



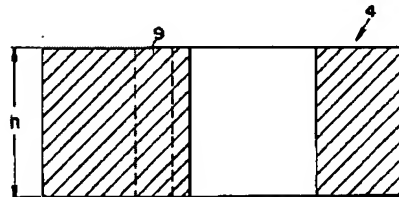
[FIG. 9]



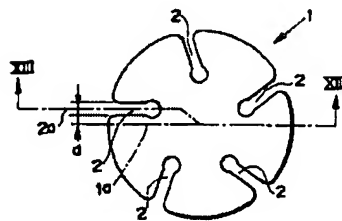
[FIG. 10]



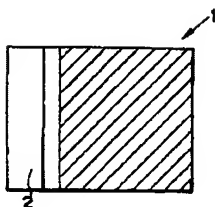
[FIG. 11]



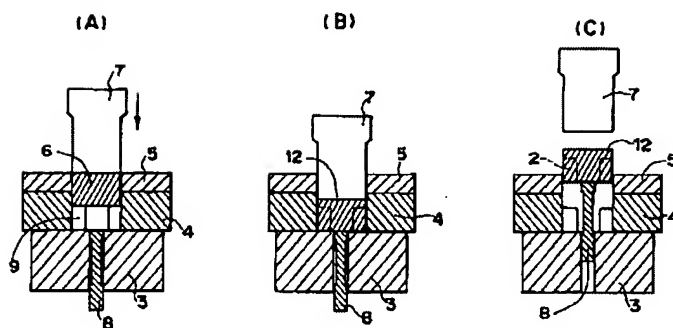
[FIG. 12]



[FIG. 13]



[FIG. 14]



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